Research on the Visual Efficiency of Artificial Light Environment under Different Culture and Education Background

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Abstract: The human condition is commonly acknowledged to be dependent on light. However, the quality of light varies greatly in nature and in controlled situations, raising the question of which artificial light properties are most conducive to learning. The use of lighting in buildings is a growing area of study, a concern for visual efficiency as it relates to indoor light environment quality is now included in the notion of sustainable design. A research was conducted in the form of an experiment in order to better understand the visual efficiency of the artificial light environment, specifically on students in a classroom. The basic objective of this paper is to investigate the lighting in the classroom, as well as to determine the subjectively preferred light environment and the optimal light environment learning mode through an experimental approach, to evaluate and assess the impact of artificial light on different students in a classroom, to comprehend the impact of color temperature and illuminance while taking into account ethno-cultural variety and the personality of the students using numerous factors such as learning efficiency, learning difficulty level, learning recovery and as well as other personal criteria such as age, educational background, and previous academic experience. According to this study, people's favorite the light environment of 1000 lx and the influence of illumination on people's preference is greater than color temperature. There are differences in the learning efficiency because of the different educational background of the subjects under the same light environment. The best learning efficiency of the Congolese subjects occurs when the color temperature and the illuminance of the artificial light environment are 4200 K and 625 lx, respectively, and for the Cameroonian subjects, it happens in the artificial light environment with the color temperature of 5510 K and the illuminance of 700 lx. The goal research result is to offer a theoretical foundation for the design and administration of artificial light environments in university classrooms in the future.

Keywords: Artificial light, Color temperature, Illuminance, Visual efficiency

1. Introduction

Natural and artificial lighting both have an impact on people's health, mood, wellbeing, and attentiveness despite the race according to research [1,2]. Studies have found that light intensity and color temperature of artificial lighting have an impact on Blood pressure, heart rate [3], and other physiological functions in the human body [4,5], openness to lighting with various illuminances, and correlated color temperature can influence the nature of rest, the disposition, alertness, and seen self-viability of the subjects contemplated [6,8]. Since the industrial revolution, People have been spending more and more time indoors leading artificial illumination to demonstrate the ability to at least partially compensate the processes that balance the body, mind, and emotions [9] that used to be played by sunlight. When it comes to expressing emotions, lighting plays an important role. Brighter light has been shown in studies to heighten emotions, whereas low light does not erase feelings but keeps them stable [10]. Lighting can be used in many circumstances both to enhance the visual appeal of an architectural space [11] or to create an ambience in that space which will have an effect on people's emotions and a direct impact on the user's well-being [12]. The parameters utilized to generate illumination settings that address it are brightness, color, direction, contrast, and time [13], in addition to the physiological and psychological impacts of various types of lighting. Research has shown that certain lighting environments can improve human performance [14], for example, artificial lighting has been shown to improve working speed, accuracy and performance of tasks in studies [15,16]. Although these research works discovered some impacts, they do not conclusively prove or disprove the visual efficiency of artificial light environment under different culture and education background. In this study, we seek the body of knowledge by looking into how classroom lighting may affect student's concentration in collegiate schools taking into account the ethno cultural diversity of the learners. The experiment that designs artificial light environment in order to study visual efficiency in the classroom was carried out. An exploratory test had been conducted at the health lighting laboratory of China to analyze the distinctive behavior, learning capacity, leaning challenges and mental wellbeing of the subjects under the distinctive light color temperature and illuminance. This experiment aims to obtain the preferred subjective light environment and the best light environment of learning in it, in the hope of providing a theoretical basis for the design and management of the artificial lighting environment in university classrooms in the future.

2. Literature review

Researching and incorporating related literatures on the effects of light on human health, such as rhythm, it has been established that a light source has an impact on the human body which are among others the Visual and non-visual influences on physical function [16,17]. First and foremost, the author is concerned about non visual effects, mental strain, and physiological functions knowing that the subject of light and health has also become a hot topic of international concern [18]. At the moment, there are two major kinds of evaluation methodologies for daylighting and artificial lighting for non-visual impacts in buildings in the world. The first category was proposed quite early on, and it is concerned with the approach of evaluating a static light environment. This is the most common

form of evaluation procedure. It's used to calculate the non-visual effect value of a given point in real time. the second type is just appearing in the near future; the more mainstream methods are the evaluation methods for the dynamic natural light environment.

For non-visual effect, one of the most well-known instances of a circadian behavioral rhythm is the human sleep–wake cycle, which consists of periods of sleep at night and awake throughout the day. The interplay of two variables causes it: the circadian desire for waking and the homeostatic sleep pressure. The time and intensity of sleep have been studied in a variety of experimental situations. The relationship between this circadian "process C" and the homeostatic "process S" has been conceptualized in the well-known "two-process model of sleep" [1,17], which explains the time and intensity of sleep in a variety of experimental scenarios. Indeed, the circadian pacemaker in the SCN and the sleep homeostat have been demonstrated in well-controlled research to interact in a way that allows for consolidated periods of awake and sleep during the day and night, respectively [15,19].

3. Method

In the study, the experiment mainly involves three aspects: first, the test environment and conditions, then test devices, equipment, and participants, and finally, the experimental process.

3.1 Test environment and conditions

The experiment was conducted in a precise and concise way in the optical laboratory environment. The lighting system is made of LED flat lamp, where the color temperature and the illuminance of the light can be adjusted from an application on a smartphone.

3.2 Test participant, devices and equipment

To diversify and make the test more dynamic, a total of 12 male volunteers belonging to Africa from various age groups, grades, and faculties were selected to participate in the test under the 9 different artificial light environments. TR-74Ui-H lux meters were selected to record the illuminance of indoor lighting.

3.3 Experimental process

The experimental process is as follow: the first step is to adjust the lights parameter of the experimental area according to the regulation schema of the light environment conditions shown in Table 1, and to invites the student to sit down and present him the test paper while letting him the time to adapt to the light. Begins with the first question (Q1) which is the KSS sleepiness scale and after, perform the Anfimov [17] letter recognition table (Q2) then follow with digit breadth test (Q4). During the test we make sure the paper numbers are parallel to the position of human eye. The next step is to ask the subject to answer the fifth question which is to choose between the proposed items how much

the like of the light environment and finish the test paper with answering the KSS sleepiness scale again (Q1). After the first paper, change the light environment and let the subject rest for 5 minutes in the new environment to adjust the sleepiness and the fatigue, and perform each light environment experiment in accordance with the above mention experimental procedure.

Table 1 Regulation schema of the light environment conditions

Parameter	A1B1	A1B2	A1B3	A2B1	A2B2	A2B3	A3B1	A3B2	A3B3
Color temperature (K)	2900	2900	2900	4000	4000	4000	5000	5000	5000
Illuminance (lx)	300	500	1000	300	500	1000	300	500	1000

4. Results and discussion

4.1 Light environment preference

Fulfillment assessment test (Q5) of each subject in various light conditions was carried out, and the very dissatisfied was set to 1 point, not very satisfied to 2 focuses, and the moderate to 3 focuses. A score of 4 for fairly satisfied and 5 for very satisfied were set. As shown in Fig. 1, each type of light environment has the maximum and minimum values of the preferred light, the small square dots represent the average preference value of the 12 subjects in each light environment. The colored dots next to each light environment boxplot represent each group of samples. From Fig 1, it can be seen that the data of each light environment conforms to the law of normal distribution. It can be seen that people's favorite types of light environment are (4000 K, 1000 lx) and (2900 K, 1000 lx), so far it is evident that people have a preference for the light environment of 1000 lx. The difference in rating is the biggest for A1B3, A2B2, and A2B3, some people like it and others don't like it. The influence of illumination on people's preference is greater than color temperature. Under the same illumination, people prefer warm color temperature, and the evaluation value of intermediate color temperature is similar to high color temperature. The explanation for this could be that the warm color temperature provides them a sense of security and comfort, and they can feel safe and secure with it. When you combine this with a reasonable illuminance such as 1000 lx, you get the ideal light environment for people. It could also be due to the climate and atmosphere they are used to in their home country when you consider that Africa is a mostly sunny continent.
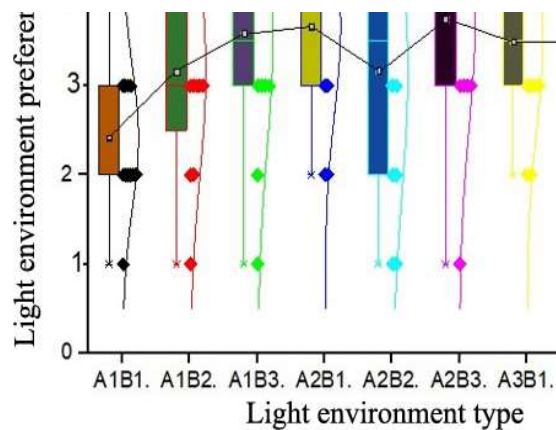
Figure 1 Light environment preference

4.2 Relationship between learning efficiency, color temperature and illuminance

From the analysis of the data gotten from the experiment, it has been found that under the light environment A2B3 (4000 K, 1000 lx), the students' learning efficiency is the highest, with scores above 25 points, while in the light environment A1B1 (2900 K, 300 lx), the learning efficiency of students is the lowest, only 7 points score at the lowest. Compared to the illuminance, the learning efficiency is greatly affected and correlated by the color temperature, and students under 500 lx and 1000 lx light environments have an excellent learning efficiency, but is quite low under the 300 lx light environment. Therefore, the artificial light environment indicator (color temperature, illuminance) impressively affects the learning efficiency of the subjects.

The results shows that there are differences in learning efficiency between different subjects. Specifically, it mostly related to the information data of each subject such as the age, the educational background and the nationality. Interestingly, the variation trend of learning efficiency with color temperature and illuminance is similar in the same country. Here an analysis of experiment results on the Congolese and Cameroonians subjects was conducted to find the factors that could influence these results. As shown in Fig. 2, a fitting diagram curve based on the second-degree polynomial was created for each country which reflect the relationship between the average learning efficiency and the two factors of color temperature and illuminance. Meanwhile, the experimental data of the subjects with the highest learning efficiency and the subjects with the lowest learning efficiency were also performed three-dimensional surface fitting. Table 2 lists the fitting formulas between the learning efficiency of the subjects with the color temperature and illuminance. Right after obtaining the fitting formula, the color temperature and the illuminance of the artificial light environment required by the subjects to achieve the highest learning efficiency through calculations can be obtained. It can be seen that under the same light environment, although there are differences in the learning efficiency due to the different educational background of the subjects, the change of the light environment will help the subjects to greatly improve it. It is interesting that the best learning efficiency of the Congolese subjects occurs when the color temperature is 4200 K and the illuminance is 625 lx, and for the

Cameroonian subjects, it happens when the color temperature and the illuminance of the artificial light environment are 5510 K and 700 lx, respectively.
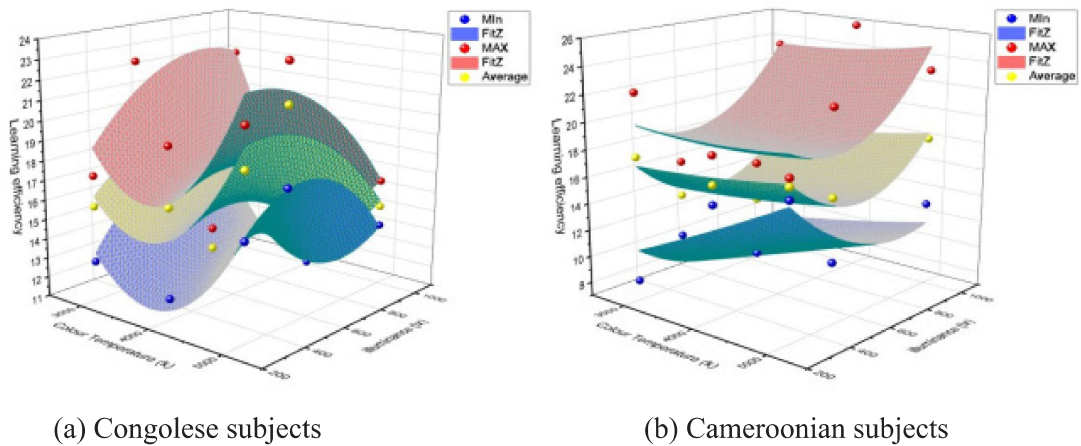

(a) Congolese subjects   (b) Cameroonian subjects

Figure 2 Average fitting diagram of Cameroonians and Congolese subjects in function of learning efficiency color temperature and illuminance

Table 2 Fitting formula for learning efficiency of the subjects from Cameroonians and Congolese

Subject	Learning efficiency LE fitting formula	Best learning efficiency	
		Color temperature T[K]	Illuminance E[lx]
Congo	$LE = 46.43 - 0.02E + 0.032T + 3.06 \times 10^{-6} E^2 - 1.36 \times 10^{-5} ET - 4.32 \times 10^{-6} T^2 (R^2 = 0.818)$	4200	625
Cameroon	$LE = 25.56 - 0.0008E - 0.03T + 1.67 \times 10^{-7} E^2 + 2.598 \times 10^{-5} ET + 2.92 \times 10^{-7} T^2 (R^2 = 0.910)$	5510	700

5. Conclusion

Studying classroom lighting from the perspective of visual efficiency will be an important development trend. This article using the experimental testing to investigate the visual efficiency of artificial light environment under different culture and education background, with the goal of maximizing the use of artificial lighting, to determine what light environment is helpful to learners' learning state. According to this study on the light environment preference of artificial light, people's favorite the light environment of which color temperature and illuminance are 4000 K and 1000 lx, respectively, or the light environment with the color temperature of 2900 K and the illuminance of 1000 lx. It is evident that people have a preference for the light environment of 1000 lx and the influence of illumination on people's preference is greater than color temperature. By studying the relationship between learning efficiency, illumination and color temperature, it has been found that although there are differences in the learning efficiency because of the different educational

background of the subjects under the same light environment, the change of the light environment will help the subjects to greatly improve it. Interestingly, the best learning efficiency of the Congolese subjects occurs when the color temperature is 4200 K and the illuminance is 625 lx, and for the Cameroonian subjects, it happens in the artificial light environment with the color temperature of 5510 K and the illuminance of 700 lx. Future investigations should include a larger sample size of subjects with multiple age levels and countries to provide further evidence that two factors of color temperature and illuminance are correlated to the subjects' visual efficiency.

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